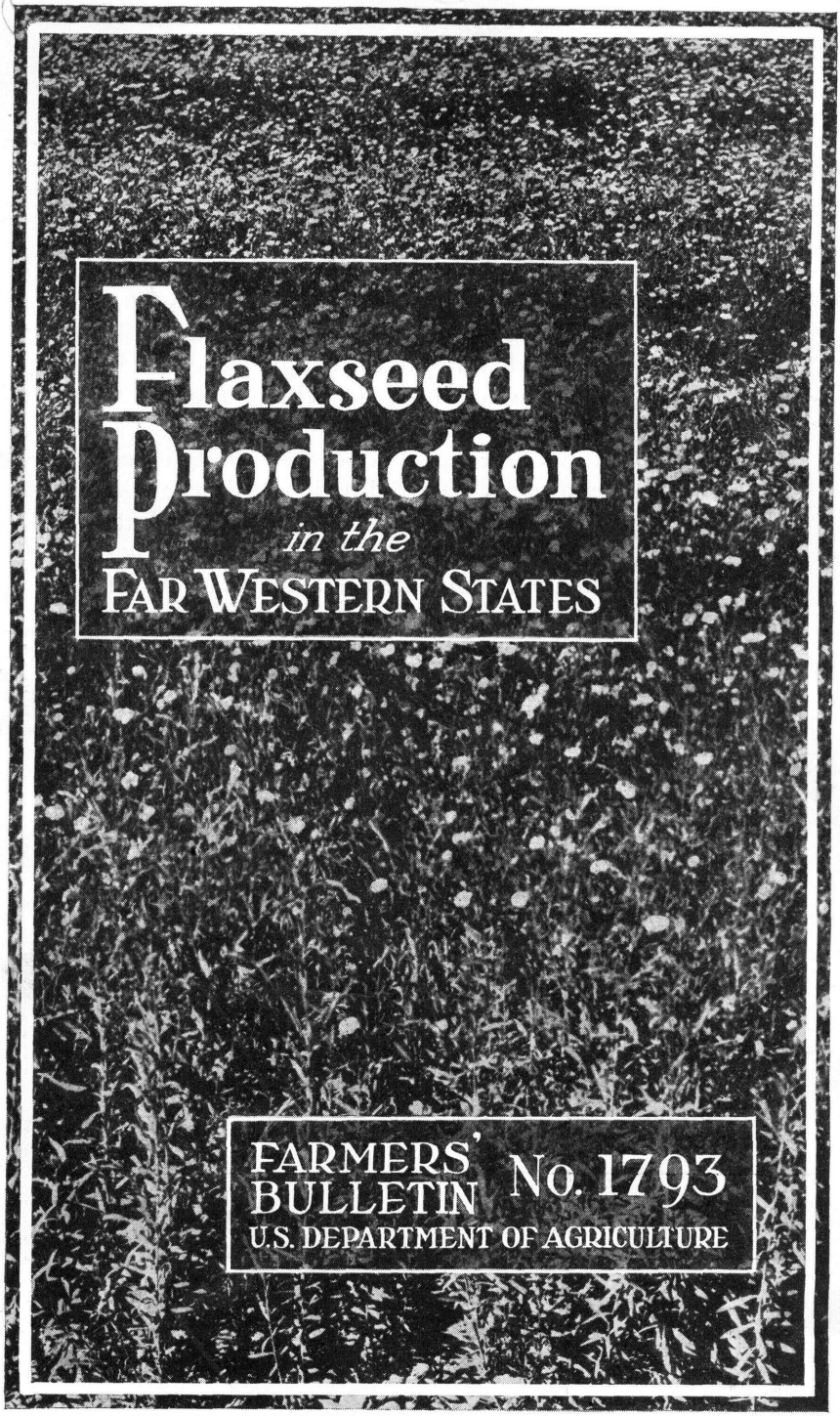
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THE PRODUCTION OF FLAXSEED is a new industry in California. The crop, however, has been grown to a limited extent for 40 years or more in Oregon, Washington, and Idaho. Flax is grown for fiber or for seed called flaxseed or linseed, and distinct varieties are grown depending on whether seed or fiber is the principal product desired. This bulletin treats only of its cultivation for seed.

It is highly important that flax be grown only on clean land. The crop does best following either a clean-cultivated row crop or a legume. A rotation that includes a cultivated crop and a legume is very satisfactory. Where irrigation water is available in California, sesbania or some other legume may be grown during the summer and plowed under as green manure before seeding flax.

Flax is a cool-weather crop and should be sown as early in the spring as possible in the Pacific Northwest. The principal rainfall there occurs during the late fall and winter, and early seeding permits the crop to mature before the dry weather of summer occurs.

In California, it is the general practice to seed in the fall. In the Imperial Valley materially higher yields usually are obtained from seeding in late October or in November than from later seeding. This is true also in the San Joaquin Valley in seasons when the crop escapes injury from frost. There is considerable hazard from frost in the central valleys of California, and the safest date of seeding flax has not yet been fully determined.

Washington, D. C. Issued September 1937

FLAXSEED PRODUCTION IN THE FAR WESTERN STATES[1]

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HISTORY OF FLAX IN THE PACIFIC COAST STATES

FLAX, FOR SEED, has been grown to a limited extent in Oregon, Washington, and Idaho for 40 years or more, and in recent years 2,000 to 5,000 acres of fiber flax have been grown annually in the Willamette Valley of Oregon. The first important commercial production of flaxseed in California was in 1934, when about 11,000 acres were harvested in the Imperial Valley.

The flax plant (*Linum usitatissimum* L.) is the source of two valuable products, flaxseed and linen fiber. In growing the crop, however, distinct varieties of seed flax or fiber flax are sown, depending on whether seed or fiber is the principal product desired. This bulletin treats of growing the crop for its seed, known in commerce as flax, flaxseed, or linseed. The coarse ripe straw of the seed flax varieties, as usually grown, does not yield a fiber suitable for spinning. The fiber of the threshed straw is sometimes separated for use as upholstery tow, insulating material, and in rugs. It may also be used in the manufacture of writing paper and cigarette paper.

Flax for fiber was one of the first crops introduced from the Old World. In Colonial times nearly every household had its patch of flax for the manufacture of homemade linens. The manufacture of linseed oil was begun in New York and Pennsylvania soon after 1800. Flax for fiber was grown in Oregon about 90 years ago. According to one record it was first planted by Albert Johnson in Yamhill County, the Willamette Valley, in 1846. No doubt, other settlers grew the crop about that time.

[1] This bulletin is based in a large part upon cooperative investigations of flax carried on by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Department of Agronomy, California Agricultural Experiment Station.

The commercial production of flaxseed in Oregon began as early as 1867. In a letter addressed to the United States Department of Agriculture in December 1872, G. P. Holman, an officer of the Pioneer Oil Co., Salem, Oreg., wrote that a mill for the manufacture of linseed oil was erected there in 1867 and the first run of oil was produced in December of that year. Some years later the mill produced 50,000 gallons annually, and by 1872 shipments of linseed oil were made to Washington, British Columbia, and Hawaii, in addition to supplying the requirements of the residents of Oregon. The company expected to have 5,000 acres of flax grown under contract in 1873. In 1888 a linseed mill of 12 presses was built by local interests at Portland, and this mill, now enlarged, is still in operation under the management of a large commercial linseed oil company. It provides a market for the flaxseed produced in Oregon, Washington, Idaho, and western Montana, in addition to foreign flaxseed which is sometimes imported.

The early settlers of California made occasional attempts to grow flax but without much success.

In 1915 the California Agricultural Experiment Station began experimenting with flax at several stations in the State in cooperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. These experiments indicated that flax could be grown with fair success, but because of the great demand for other crops during the World War period no commercial planting resulted from these experiments.

The recent commercial production of flax in California is the outgrowth of experiments begun in 1927 by the writers at the Imperial Valley Experiment Station, near El Centro, Calif. After considering the results of the experiments mentioned above, it appeared desirable to test a number of distinct types to determine whether any variety was well adapted to local conditions as a fall-sown irrigated crop. The junior writer, foreman of the station, seeded 10 varieties on November 14, 1927. These were harvested in April 1928 and yielded an average of 25 bushels an acre, the highest yield, 31.2 bushels, being obtained from Punjab (C. I.[2] 20), a selection of Indian flax. In 1930 a small increase plot of the Punjab variety produced 212 pounds of seed, at the rate of 28½ bushels per acre.

In August 1930, W. W. Weeth succeeded the junior writer as foreman of the Imperial Valley Experiment Station. He soon became enthusiastic about the possibilities of flax production and was largely responsible for the rapid extension of the crop in the Imperial Valley. An increase field of 2 acres was harvested in 1931, and this seed was distributed to a few farmers, who harvested 110 acres in 1932 and 350 acres in 1933. All the Punjab seed produced in 1933 was used for sowing about 8,000 acres, which produced nearly 200,000 bushels in 1934.

The average acreage sown to flax in the Imperial Valley during the 3-year period 1934-36 was more than 22,000 acres a year. The Southwest Flaxseed Growers' Association, representing growers in the Imperial Valley, has been active in maintaining the purity of Punjab flax and in distributing seed of high quality. In 1935 some 20,000 acres of flax, chiefly of the Punjab variety, were harvested in the San

[2] "C. I." refers to the accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

Joaquin and Sacramento Valleys of California; this was the first important commercial acreage in these valleys. The same year about 5,000 acres were grown in the Salt River Valley of Arizona.

COMMERCE, MARKETS, AND MANUFACTURE

Flaxseed is a cash crop; very little is consumed on the farm on which it is grown. The two products of flaxseed are linseed oil and linseed meal. The oil is used in the manufacture of paints and varnishes, linoleum, oilcloth, patent leather, printer's ink, and other products. Linseed meal is used as a feed for livestock.

In recent years the production of flaxseed in the United States has been insufficient to meet domestic requirements, and large quantities of flaxseed have been imported, chiefly from Argentina. The Tariff Act of 1930 provides a duty of 65 cents a bushel of 56 pounds on imported flaxseed and 4½ cents a pound on linseed oil. Under the previous Tariff Act (1922) the duty was 40 cents a bushel on flaxseed and 3.3 cents a pound on linseed oil. The annual production, net imports, and consumption of flaxseed in the United States from 1921 to 1936 are shown in figure 1.

The principal markets for flaxseed produced in the North Central States are Minneapolis and Duluth, Minn. Because of the extensive trading in flaxseed in these markets the Minneapolis quotations commonly serve as a basis for the price paid for flaxseed in other United States markets. The linseed mills at Minneapolis consume the bulk of the flaxseed marketed there, whereas most of the seed received at Duluth is shipped via the Great Lakes to mills at Chicago, Buffalo, Philadelphia, and mills located in the vicinity of New York City. On the Pacific coast the principal linseed mills are located at Los Angeles, Long Beach. San Francisco, Fresno, and Corcoran, Calif., and Portland, Oreg.

The bulk of the flaxseed produced in the Western States is crushed and consumed in that area. Flax usually is marketed soon after harvest. In some cases it is sold directly from the combine or thresher, although generally it is recleaned before it is marketed. There are few grain elevators in the western flaxseed-producing States. Consequently the linseed mills usually purchase flaxseed directly from farmers and arrange for transportation to the mill by rail or truck. Many farmers grow flax under contract, although this is not necessary, because there is a ready cash market for flaxseed at all times.

In the manufacture of linseed oil the flaxseed is ground to a fine meal by being passed through a battery of revolving steel rolls. The ground meal is then transferred to a steam-jacketed cylinder or "cooker", live steam being added if the meal is very dry, and heated to near the boiling point. This heating process facilitates the expression of the oil when the meal is subjected to pressure. After being heated, the meal is pressed firmly into a mold about 13 by 32 inches on a press cloth, which then is folded over the resulting meal cake. From 24 to 30 of these cakes are placed in a hydraulic press and subjected to increasing pressure for about an hour. The presses are operated in batteries of 6, the smaller mills having 12, 18, or 24 presses and the larger mills 48 or more. The residue left after the

oil is expressed is known as linseed cake, or, if ground, as linseed meal. The pressed cake contains from 3 to 6 percent of oil, depending on the efficiency of the pressing.

A more modern type of press, known as the cage type, is efficient and economical in operation. The cage consists of a heavy steel drum about 6 feet high and oval in cross section, with the walls slotted to permit the escape of expressed oil. The cage is filled with successive

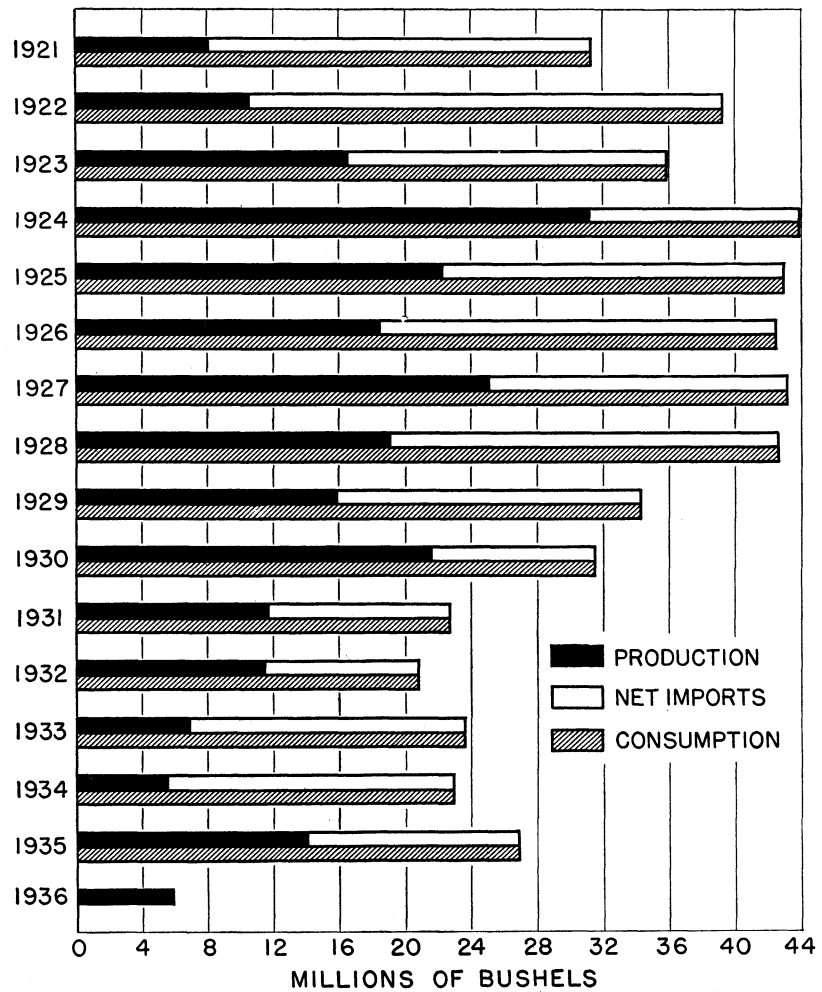


FIGURE 1.—Flaxseed production, net imports (including linseed oil in terms of seed), and consumption in the United States for the 16-year period 1921–36.

layers of ground flaxseed placed between press cloths and then subjected to hydraulic pressure by means of a heavy plunger. In another type of press, known as an expeller, the meal is fed into the machine and the oil expressed as a continuous process. This press is considered economical of labor, but it is perhaps somewhat less efficient in extracting the oil than the presses described above.

THE FLAX PLANT AND ITS SEED

Flax is an annual plant that grows to a height of 1 to 4 feet, depending upon the variety, soil conditions, and the length of the growing season. It has a distinct main stem and a short taproot. When flax is sown thickly, as for fiber, the stems rarely produce branches except near the top, but when it is sown thinly, for seed, the stems often bear two or more basal branches arising just above the surface of the soil. The flax flower has 5 petals, and the five-celled boll or capsule, when filled, contains 10 seeds but not more than 10 except in abnormal double bolls. Flax is normally self-pollinated, and very little natural crossing occurs. The flowers open at sunrise on clear days, pollination occurs at once, and the petals fall before noon. Flax plants continue to blossom for a period of 1 to 3 weeks, or longer, depending on weather and soil-moisture conditions, and the yield often depends on the length of the blossoming period. The petals of the flower are blue, pale blue, white, or pale pink in different varieties. The seeds of most varieties are brown, although in some varieties they are yellow, mottled, greenish yellow, or nearly black.

Flaxseed yields from 32 to 38 percent of oil, or about 19 pounds per bushel (56 pounds) of seed in commercial crushing. The yield of oil depends upon the variety of flax and upon the climatic conditions under which the crop is grown. In general, the large-seeded varieties yield a higher percentage of oil than do the smaller-seeded varieties. A high yield of oil usually is obtained when the crop is grown under irrigation. If drought occurs when the seed is filling—that is, within a period of about 30 days after blossoming—the seed may be shrunken and the oil content low. High temperatures, which often accompany a period of drought, are especially injurious to flax since they reduce the acre yield and the percentage of oil. A chemical test, known as the "iodine number", indicates the drying quality of the oil, or, more exactly, the quantity of oxygen the oil will absorb in drying to form the characteristic paint film. Both the quantity and quality of the oil are influenced by the climate under which the flax is grown, rainfall, temperature, and length of the growing season being especially important. The iodine number may range from 140 to over 200 under extreme climatic conditions, but the usual range is from about 170 to 190.

VARIETIES OF FLAX

As already mentioned (p. 1), flax is grown commercially for two distinct purposes, namely, fiber and linseed. Fiber flax is never grown primarily for linseed, although the surplus seed that is not required for sowing the fiber crop is generally sold on the market for crushing. The fiber-flax varieties are tall and early maturing but generally inferior to the seed-flax varieties in yield of seed. In Oregon a yield of 8 to 12 bushels of seed to the acre, or 5 bushels per ton of pulled dry flax, is considered a good yield of seed from fiber flax.

The seed-flax or linseed group consists of several more or less distinct types: (1) Wilt-resistant short-fiber flaxes; (2) common or "Russian"; (3) Argentine; (4) Indian; (5) Abyssinian; (6) Golden, or yellow-seeded; and a few others of less commercial importance.

The short-fiber flaxes, grown chiefly in the North Central States, were developed on the basis of wilt resistance and high seed yield. Buda, Linota, and Redwing belong to this group. These varieties have small brown seeds and slender stems, but are much shorter than the fiber flaxes. Bison also may be included in this group, although it has stouter stems and seeds of medium size. Bison is remarkably wilt resistant and is the principal variety grown in the North Central States and in the Pacific Northwest.

The common or so-called Russian varieties formerly were grown extensively on new lands in the Dakotas, but owing to their susceptibility to wilt they have been replaced generally by wilt-resistant varieties. Damont and Newland are strains selected from the Russian North Dakota No. 155. Newland is immune to rust but susceptible to wilt.

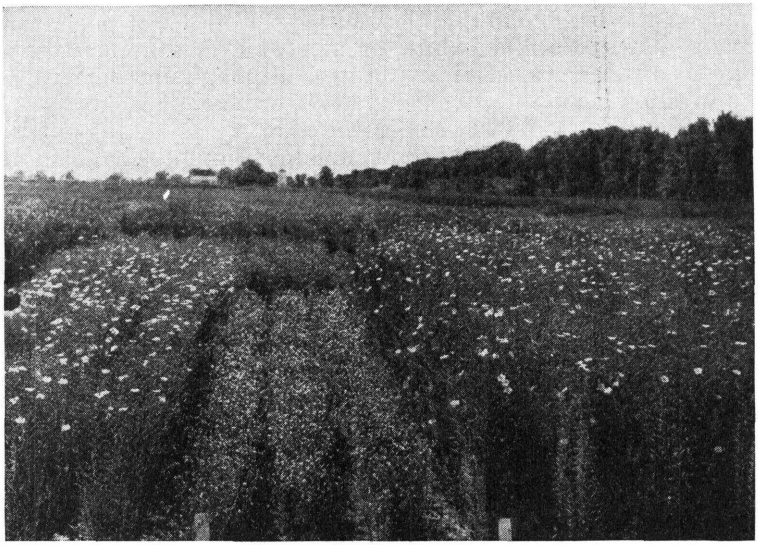


FIGURE 2.—Three varieties of flax: The shorter, early maturing Indian type 12 in the center and the taller and later Argentine (C. I. 342) at the left. A selection, California No. 2, is shown at the right. Photographed at Davis, Calif., April 23, 1936.

The Argentine flax of commerce is chiefly the Malabrigo variety, which has large open (flat) blue flowers, tightly closed bolls, and large brown seeds. The plants, as grown in the Imperial Valley, have rather stout stems, with generally two or more basal branches, and are much taller than the Indian varieties. Argentine flax may be adapted to growing in the upper Sacramento Valley of California, or in other localities where early fall seeding may not be desirable. Under such conditions it still will grow tall enough to be harvested without difficulty (fig. 2).

The Indian flaxes are adapted to a long growing season; that is, to fall seeding in mild climates. They are very short when sown in the spring in northern climates but grow much taller when fall-sown where a long growing season is possible. More than a hundred distinct strains and varieties of Indian flax have been obtained by the

United States Department of Agriculture and tested in different localities. Punjab (C. I. 20), which is grown extensively in California, is a comparatively pure variety. It was developed by continued selection for 2 or 3 years by C. H. Clark, at the Northern Great Plains Field Station, Mandan, N. Dak., from seed introduced from the State of Punjab, India, in 1913. This variety is somewhat taller and apparently more productive in California than any of the strains obtained directly from India.

The Punjab variety has blue flowers, very firm bolls, and medium-large brown seeds of high oil content. The plants grow to a height of 15 to 30 inches, depending on the length of the growing season, and have two or more basal branches which ordinarily are nearly as tall as the main stem. Under favorable conditions it continues in

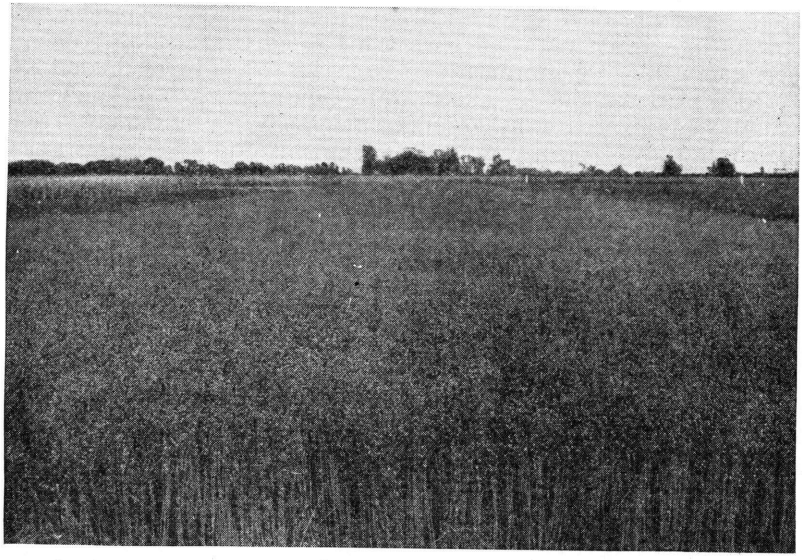


FIGURE 3.—A plot of Punjab flax at the Imperial Valley Experiment Station, El Centro, Calif. This was the fourth consecutive crop of flax on the same plot. The yield was 36.3 bushels an acre. Photographed April 20, 1935.

blossom for a period of 3 or 4 weeks and sets a large number of bolls; it is therefore a high yielding variety (fig. 3). However, it is not disease resistant as is sometimes claimed; it is susceptible to both wilt and rust, where these diseases occur. A few varieties of Indian flax are more or less wilt-resistant, and still others are resistant or immune from rust. Several of these disease-resistant strains are now being grown to determine their yields, and the better ones will be increased for distribution in case wilt appears in the Imperial Valley or in other localities where flax is grown extensively. The use of imported commercial Indian flaxseed for sowing is not recommended. Such seed is likely to be a mixture of different types and varieties. Moreover, there is great hazard of introducing flax diseases and weeds in commercial seed.

The Abyssinian flaxes are short, fine-stemmed, much-branched, and leafy with blue flowers and small brown or yellow seeds. Abyssinian

Yellow-seed (C. I. 36) has produced high yields in California, and its seed yields a clear oil of high drying quality. It threshes more easily than Punjab because of its slightly open bolls. This character of the bolls, however, allows the seed to shatter somewhat in high winds if the crop is allowed to stand after it is ripe.

The so-called "Golden" flaxes consist of several varieties with pale-pink, nearly white flowers and medium or large yellow seeds. Bolley Golden (C. I. 644) is perhaps the best of this type. It has produced excellent yields at the Imperial Valley Experiment Station, and its seed yields a high percentage of oil of good drying quality. It is moderately resistant to wilt and nearly immune from rust.

Experiments with flax in the Pacific Coast States have been rather limited, and the varieties best adapted to all the soil and climatic conditions throughout this extensive area have not yet been determined. Tests are being conducted by the State agricultural experiment stations in cooperation with the United States Department of Agriculture, and the adaptation of varieties to many local conditions may soon be determined. The introduction of seed of unknown performance by linseed crushers and private growers is not recommended, however, because of the hazard of introducing plant diseases. The value of a new variety cannot be determined accurately except by carefully controlled experiments, including chemical tests of the yield and quality of oil, carried on over a period of years.

GROWING THE CROP

CROP ROTATIONS FOR FLAX

Flax is grown to best advantage in rotation with clean-cultivated crops or on fallow land kept free of weeds. It does well following beans, peas, corn, sugar beets, and other clean-cultivated row crops. Alfalfa, clover, wheat, or barley land also is suitable for flax, provided it is free of weeds.

Grain sorghum, sorgo, Sudan grass, and millet should not be followed immediately by a flax crop. Sorghum land should be fallowed for a year, or sown with a leguminous crop for soil improvement before being sown to flax. The legume may be grown either as a winter or summer crop. Some suitable winter crops for use on sorghum land are field peas, vetch, sourclover, and fenugreek. If summer crops are preferred, cowpeas, soybeans, guar, or sesbania may be used. The choice of crop should depend on soil and climatic conditions and whether it is grown for feed, or only for soil improvement. The injurious after effects of sorghums, including Sudan grass, may be very serious and result in crop failure if flax is seeded before the sorghum roots and stems have decomposed and soil fertility has been restored.

Flax may follow flax, but when this is done a quick-maturing cover crop usually is grown during the summer and turned under before the land is prepared for the second crop of flax. For example, in the Imperial Valley of California, where flax is harvested in May, the land may be prepared immediately by disking and seeded to sesbania, guar, cowpeas, or soybeans. With plenty of water for irrigation, these crops will be ready to plow under in 60 to 90 days. This

allows ample time for the green manure to partly decompose before flax is seeded again in November. When this practice is followed, flax may be grown on the same land for a number of years without diminishing yields. This cannot be done, however, on nonirrigated or dry land. Although flax can be grown for 2 or more years on the same land, as a general rule, it can be grown to best advantage in a regular crop rotation where the land is relatively free of weeds and fairly well supplied with nitrogen, as following a legume, and where a firm seedbed can be prepared at small expense.

CONTROL OF WEEDS

Flax is a poor competitor with weeds. Flax seedlings are relatively slow in starting growth and establishing a thick cover. The control of all weeds is essential to profitable flax production. Weeds

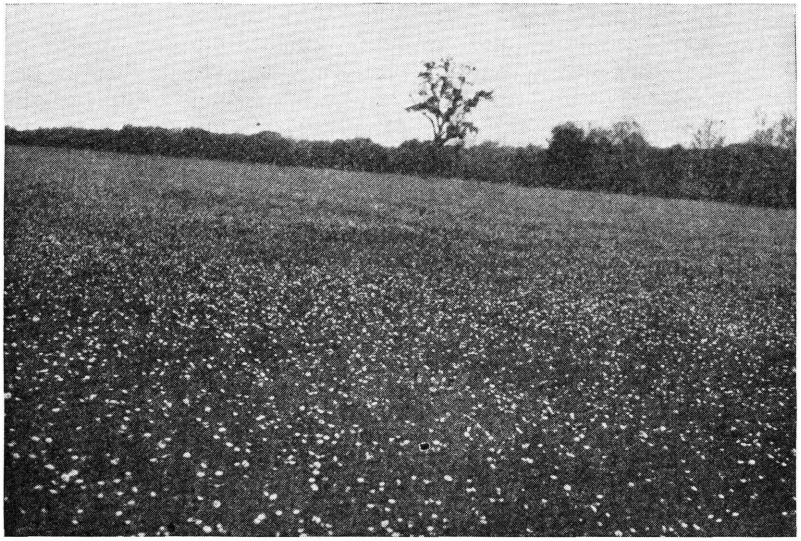


FIGURE 4.—A 190-acre field of Punjab flax on the R. W. Hanna Ranch near Vina, Calif. This clean field was in cultivated crops, corn and beans, for two seasons prior to seeding to flax. Flax was sown December 10, 1934. Photographed April 30, 1935.

not only shade, crowd, and reduce the growth of the flax plants and use moisture and soil fertility, but they add greatly to the difficulty and expense of harvesting. Weed seeds are objectionable in the threshed flaxseed. Some weed seeds, such as mustard, yield an oil in the process of crushing, but it is not a drying oil and tends to lower the drying quality of the linseed oil. Other weed seeds absorb oil in the crushing process, and thereby reduce the quantity of oil extracted from the flaxseed. It is probable that the yield of flax is often reduced from 10 to 50 percent in weedy fields, and in some fields or parts of fields the crop is totally destroyed.

Because weeds are not easy to control or eliminate in flax fields, land known to be very weedy should be avoided. In any case, every effort should be made to rid the land of weeds and weed seeds before seeding to flax. Methods of control will vary somewhat, depending

on the climatic conditions and the kind of weeds to be combated. In sections where fall or winter seeding is practiced some weed seeds will not germinate until the warmer weather of spring, and the resulting weeds cannot be destroyed before seeding. However, if the land is thoroughly cultivated as soon as possible after irrigation or rain, many weeds will be destroyed. If time permits, a second cultivation 10 days after the first one will be of great benefit in eliminating weeds (fig. 4). Where irrigation is not practiced, it is important that the cultivation be rather shallow, because the seedbed should remain firm; moreover, deep cultivation tends to bring additional weed seeds to the surface. In some sections delayed seeding offers the grower an opportunity to eradicate weeds more completely. However, any delay in seeding, after the proper date, may be at the expense of a lower yield of flaxseed. The object should be to eliminate weeds as nearly as possible, and still seed the flax at the optimum date for highest yields. The establishment of a good stand of flax will, of course, aid in the control of weeds.

The most common annual weeds are several species of mustard, wild oats, sourclover, malva, lambsquarters, sunflower, peppergrass, tarweed or fiddle-necks, redroot pigweed, dogfennel, cornflower, darnel, and barnyard grass. Many of these are winter annuals in the mild climate of the Pacific Coast States. Perennial weeds include Canada thistle, quackgrass, and morning-glory. The control of these perennial weeds is a special problem. Land infested with such weeds had better not be used for flax. It is important, of course, to make sure that flax used for seeding is free from weed seeds, especially of noxious weeds and of weeds new to the locality.

PREPARING THE SEEDBED

The method of preparing a seedbed for flax depends on the previous crop grown, the kind and abundance of weeds present, the texture of the soil, and whether or not the flax is to be grown under irrigation. Whatever the conditions may be, the ultimate achievement should be a clean, smooth, firm seedbed. Poor stands frequently are the result of seeding too deeply in loose soil. Land in alfalfa or other perennial crops should be plowed in the summer or early fall for flax. Plowing may not be necessary if the land was in a clean-cultivated annual crop, such as corn, sugar beets, beans, lettuce, or cantaloups, and disking, harrowing, and leveling to form a smooth, level surface will suffice. Wheat or barley land should be plowed soon after the grain crop is harvested in the spring or summer and remain fallow until time to prepare the seedbed for flax in the fall. Where irrigation water is available, wheat or barley land may be disked after harvest and a cover crop grown before the land is plowed for flax.

If the flax crop is to be grown under irrigation, the levees or borders should be made at the time the land is plowed or disked (p. 14). The land should be thoroughly irrigated some 10 or 15 days before it is seeded. This irrigation settles the soil firmly, germinates many weed seeds, and supplies sufficient moisture to maintain the growing flax for several weeks. When the land has dried sufficiently, after this preirrigation, a thorough but shallow cultivation should

be given. The primary object of this cultivation is to destroy weeds and at the same time leave the soil in a firm, moist condition best suited to quick germination of the seed. If the land is very weedy, a second cultivation before seeding it to flax may be an advantage. These same tillage practices are applicable also to the preparation of nonirrigated land after rain in the fall.

After disking and harrowing to eliminate weeds, it is a common practice to firm the soil with a packer or roller. Where flaxseed is produced by power-farming methods, the disk, harrow, packer, and drill often are hitched to the tractor in tandem fashion, and seedbed preparation and seeding are done in one operation.

The proper implements to be used in preparing the seedbed depend largely on the type of soil. The important thing is to leave the soil firm and even so that the seed may be drilled at a uniformly shallow depth and to maintain moisture near the surface.

METHOD AND RATE OF SEEDING

Broadcasting the flax is not recommended because the seed cannot be distributed evenly on the land. When the seed is broadcast and harrowed in, some of it is covered too deep and some too shallow. This results in uneven germination of the seed and consequently in uneven stands. In addition, more seed is required in broadcasting than in drilling to obtain an equal stand.

Seeding with a grain drill at a depth of about 1 inch is the preferred method. The exact depth of seeding, however, will depend largely on the soil type and the depth to available moisture. The seed should be sown in moist soil. In light or dry soils this may require drilling the seed at a depth of 2 inches or more. This deeper seeding is practiced in the Imperial Valley, where there is little danger of heavy rains to compact the soil. Where heavy rains are likely to occur the deeper seeding is not recommended.

Probably the most satisfactory drill for seeding flax is one with a shoe-type furrow opener and individual press wheels. One advantage of this type of drill is that it presses the soil around the seed so that the germination that results is better and more uniform. Comparable results may be obtained from other types of drills by attaching a packer behind the drill, as shown in figure 5. This firms the soil about the seed. No harrowing should be done after the seed is drilled, as this would cover many seeds too deeply.

If the flax crop is to be grown under irrigation, it is usually advantageous to run the drill crosswise to the borders or levees. This has a threefold advantage, namely, it tends to fill the furrows on each side of the levees, it seeds the top of the levees to flax, which helps to check the growth of the weeds, and the drill furrows assist in spreading the water for more uniform irrigation. In addition to these advantages, the shaping of the levees at this time will aid greatly in crossing them with harvesting implements. A higher yield of flax can be obtained if the levees or borders are sown to flax, and there will be fewer weeds on the borders.

The rate at which flax should be seeded depends on the variety, that is, size of seed, and whether or not the crop is to be grown under irrigation. The usual rate recommended for irrigated land is

3 pecks, or 42 pounds, an acre. The same rate may apply to non-irrigated land, provided the rainfall is sufficient to maintain ample moisture throughout the growing season. In drier sections 2 pecks, or 28 pounds, an acre is sufficient. The heavier rate of seeding insures a better stand and helps somewhat to control weeds. It is not recommended unless moisture is plentiful.

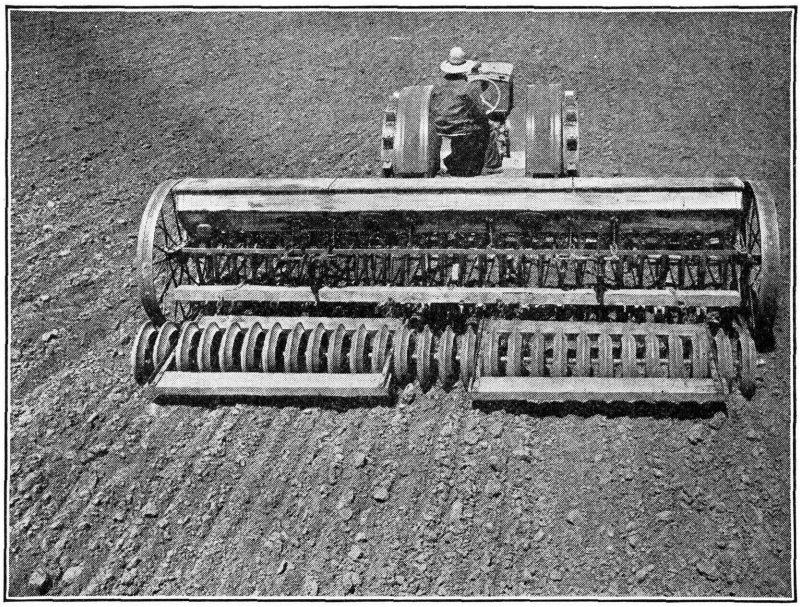


FIGURE 5.—A type of packer with wedge-shaped wheels designed to firm the soil and still leave the surface somewhat ridged to prevent soil blowing. The packer can be attached to any grain drill.

TIME OF SEEDING

Because of the great range in climatic conditions in the Western States, it is obvious that the best date of seeding will vary considerably according to latitude and elevation. The subject, therefore, is discussed under (1) spring seeding as practiced in the Pacific Northwest, and (2) fall seeding as practiced in the Imperial and San Joaquin Valleys of California.

SPRING SEEDING

Flax is a cool-weather crop, and therefore, as a general rule, seeding should be done as early as possible in the Pacific Northwest, so that the crop will be nearly matured before the hot weather of early summer comes on. In this area of winter rainfall early seeding is especially important, as the crop can make more efficient use of soil moisture if its growth is made during the cool season and before the soil moisture is reduced or exhausted in early summer. Early seeding is perhaps the most important factor in flax production in Oregon, Washington, and Idaho, as both acre yield and high

quality of oil depend on having the crop mature as early as possible. In the Willamette Valley of Oregon flax may be sown safely from March 20 to April 10, and in different sections of Idaho and Washington the date of seeding may range from April 1 to May 1. In these States early sown flax is rarely injured by spring frosts.

Flax is much more resistant to frost injury than is generally recognized. Even in the seedling stage, flax will stand a heavy frost; when the plants have made some growth they usually will endure a temperature of 25° or even 20° F. without injury. The injury from cold depends on several factors, including stage of growth, previous "hardening" by cold, length of exposure, soil-moisture conditions, and weather conditions following the freeze.

FALL SEEDING

In most sections of California and Arizona, flax is sown in the fall or early winter. In the Imperial Valley the results of experiments conducted for several years near El Centro show conclusively that the best date of seeding is from October 20 to November 20. Seeding as late as December 15 or later usually results in much lower yields. The same appears to be true in the San Joaquin Valley, although the hazard of freezing temperatures during the winter is somewhat greater in this valley. It was observed, however, that flax sown in November 1936 was injured by the exceptionally severe freezing in January 1937 much less than was flax sown later.

As the production of flax in the great interior valleys of California may depend largely on the hazards of frost injury, it seems desirable to consider in some detail what these hazards are. In January 1937 a minimum of 17° F. was recorded at El Centro and at Brawley in the Imperial Valley; 14° at Coalinga, 19° at Fresno, and 20° at Hanford in the San Joaquin Valley; and 17° at Red Bluff and 22° at Sacramento in the Sacramento Valley. Temperatures lower than these were reported by farmers. Notwithstanding these low temperatures, very little injury to flax occurred in the Imperial Valley, and early-sown flax survived in most localities in the San Joaquin Valley.

In a letter of February 18, 1937, W. W. Weeth, of Coalinga, Calif., reported that a temperature of 10° F. occurred on January 21 at his ranch and that eucalyptus and peppertrees were badly injured or killed. In view of this severe freeze it is surprising that flax survived at all. In plots of flax shown by Mr. Weeth at 15-day intervals there was very little permanent injury to flax sown October 15, November 1, and November 15, whereas the seeding of December 15 was nearly a total loss, and the seedings of December 1 and January 1 suffered a loss of 50 percent in stand. Flax sown January 15, a week before the freeze, came up with fair stands. These results indicate the relation of the stage of growth of flax to cold resistance.

In most cases of frost injury to flax before blossoming occurs, only the more tender shoots are frozen, and the plants recover quickly by forming new branches. In the blossom and green-boll stage, on the other hand, flax is liable to be greatly injured if hard frosts occur. In this stage the flower buds and the immature seeds are killed by

freezing temperatures, and although blossoming is resumed after 2 or 3 weeks, the final yield is reduced. It is the chance of frost during the blossoming stage in late February and March that is perhaps the greatest hazard to flax production in the San Joaquin and Sacramento Valleys of California. However, most flax growers in the San Joaquin Valley prefer to seed in early November despite the danger of frost, as their experience has shown that higher yields are obtained from November seeding than from later seeding. In the Sacramento Valley it probably would be safer, on an average, to seed flax somewhat later, namely, in December or January, and thus avoid loss or damage from frost.

The Weather Bureau records at Fresno, Calif., covering the winter period for 51 years (September 1887 to March 1937), show that a minimum temperature of 28° F. or lower occurred 23 times in December, 26 times in January, 8 times in February, and only once in March. A temperature of 25° or lower occurred 5 times in December, 12 times in January, and only twice in February. Such temperatures are not liable to do much, if any, damage to flax in the vegetative stages before it blossoms. On the other hand, a temperature of 30° to 32° may do marked injury if it occurs during the blossoming or green-boll stage. At Fresno, a temperature of 31° or lower has occurred 22 times in February but only 3 times in March. In view of these records and the experience of flax growers during the last three seasons it is evident that there is a considerable hazard of frost injury, and the grower should decide whether to seed in November and assume the risk of frost injury or seed later and avoid the hazard of frost but expect a somewhat lower yield of flaxseed.

IRRIGATION

Flax is a relatively shallow-rooted crop. Therefore, heavy irrigation is not necessary or desirable. Frequent light irrigations to maintain ample moisture in the root zone are more beneficial and economical than heavy irrigations at long intervals.

The number of irrigations required to produce a maximum yield depends largely on the type of soil, the date of seeding, and weather conditions. In some sections where little or no rain falls during the growing season, as in the Imperial Valley of California and the Salt River Valley of Arizona, usually four or five irrigations applied at the right time will insure a maximum yield. Where winter rainfall occurs, irrigation may be considered necessary only to supplement the normal rainfall.

Where the land is comparatively level, irrigated fields usually are laid off in narrow lands called "checks" bordered by low ridges of soil called "borders" or "levees", the irrigation water being turned into the checks through gates in the ditches at the higher edge of the field.

The soil type and the head of water available should be given consideration in determining the length and width of the lands or checks. The more sandy and porous the soil, and the smaller the head of water available, the narrower the checks should be for economical irrigation. For example, if the head of water delivered

to each check is only 1 cubic foot a second (450 gallons a minute) and the soil is a sandy loam, the checks should be about 30 feet wide and 300 feet long. On clay soils the length may be increased to 450 feet. If the head of water delivered is from 2 to 4 second feet, the checks on loamy soils may be 40 feet wide and 450 feet long, and on clay soils the width may be 50 feet and the length 600 feet or more.

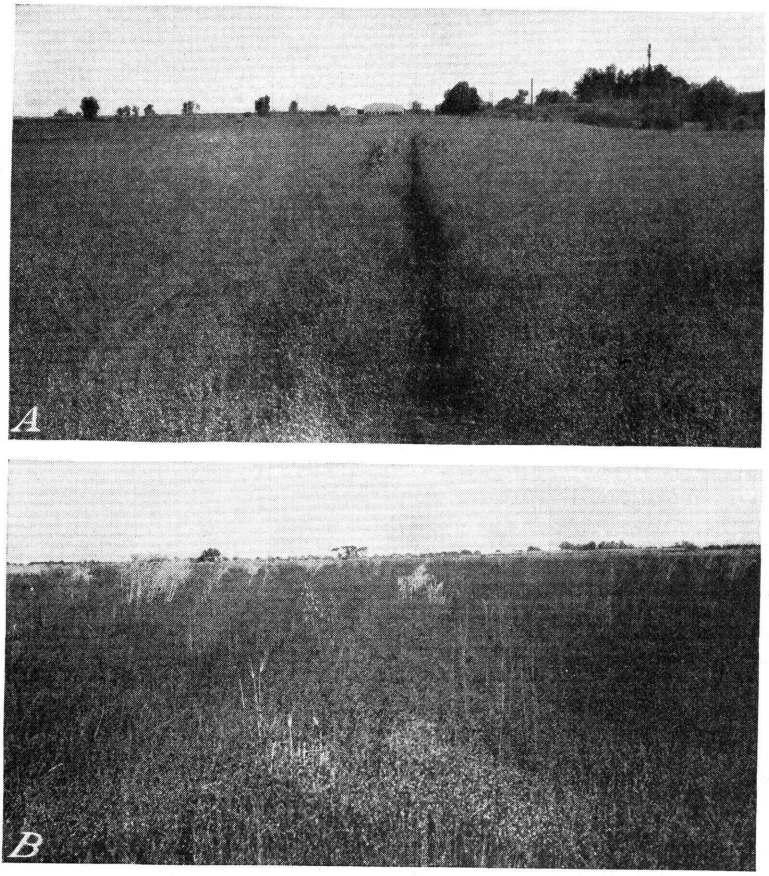


FIGURE 6.—Fields of flax in the Imperial Valley of California showing (*A*) a high narrow border and (*B*) a low wide border completely covered with flax.

Large checks can be harvested more easily than small ones. For this reason, it is not uncommon to make checks 60 feet wide and one quarter mile (1,320 feet) long. However, if water is an important item in production costs, it is very doubtful if checks larger than those recommended above are advisable.

The loss of land occupied by borders may be largely avoided by rounding the borders or levees and seeding them to flax by drilling the checks crosswise. This establishes a stand of flax on the borders, which increases the area of land in crop, and helps to control weeds on the borders (fig. 6).

Flax should be seeded in a firm, moist seedbed. This necessitates irrigation or rain before seeding. If the seedbed has been properly prepared, additional irrigation should not be needed for 30 days or more after seeding. Irrigations should be applied as needed to maintain an even supply of moisture in the soil to a depth of 2 feet or more during the entire growing season. Probably the most urgent need for irrigation is when the flax is in full bloom and for 2 or 3 weeks after the blossoming period. When the seed bolls begin to ripen, irrigation water should be withheld in order to hasten maturity. If the crop is irrigated too late in cool weather, blooming may be prolonged indefinitely, and many immature bolls and slow uneven ripening of the crop may result. There is little danger of this, however, in the hot, dry climate of the Imperial Valley, and it is considered a good practice to supply water until the crop begins to ripen. This allows the crop to produce a maximum yield.

HARVESTING AND THRESHING

Various methods are employed in harvesting flax. The most common practice is the direct combine method. This is the most economical and satisfactory provided the flax is thoroughly ripe, dry, and free from green weeds (fig. 7).

If the field contains weeds that remain green after the flax is ripe, the use of the windrower is recommended. As soon as the flax in the windrow is dry enough to be threshed, a combine with a pick-up attachment should be used. The crop should be threshed as soon as possible because the longer flax remains in the windrow the more settled it becomes and more difficult to pick up with the combine. The windrower also can be used if the crop is to be threshed with a stationary thresher. Flax in the windrow may be loaded with a hay loader and hauled to the threshing machine.

When a combine is not available and a stationary thresher is used, the most common method of harvesting is with a grain binder. The bundles are set up in long narrow shocks that permit ventilation and thorough drying. In some cases the header or reaper, with buncher attachment, may be more economical than the binder, as the cost of twine and the labor of shocking is saved.

Flax should be fully ripe when cut and thoroughly dry when threshed. In the dry climate of the Imperial Valley, flaxseed free from dockage should contain not more than 6 percent of moisture. The United States grades for flaxseed allow 11 percent of moisture for No. 1 and No. 2 flaxseed. This percentage of moisture is safe for storage in a cool climate, though it may not be safe under high temperature.

Unless the crop is thoroughly dry, the tough fibrous stems of flax are difficult to handle with machinery, either in harvesting or threshing. Flaxseed does not shatter easily, however, and it is seldom necessary to harvest before the plants are mature and dry.

Harvesting and threshing equipment especially designed for flax is most desirable (fig. 8). However, the ordinary grain thresher is fairly satisfactory, provided the machine is tight and the proper adjustments of cylinder and fan speed are made, and flax screens of the proper size are used.

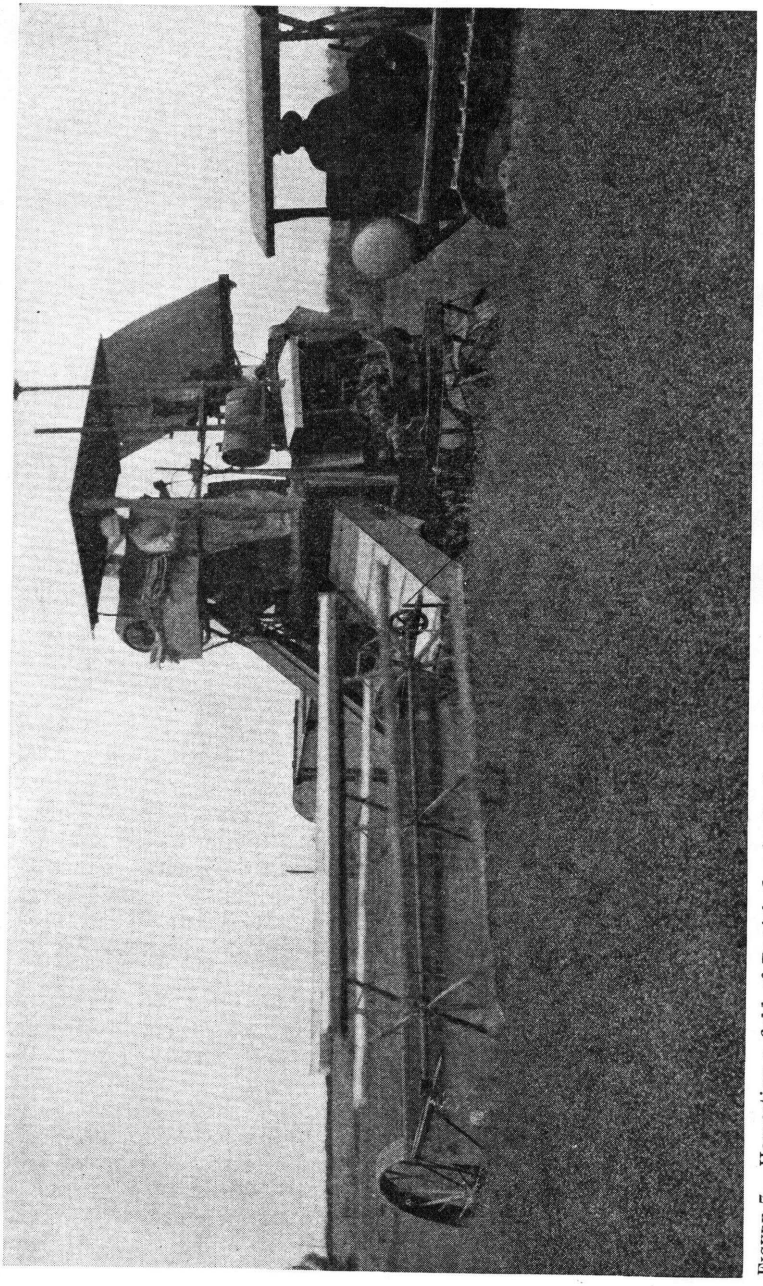


FIGURE 7.—Harvesting a field of Punjab flax in the Imperial Valley of California with the ordinary combine. The firm bolls of Punjab flax are difficult to thresh; therefore the crop should be thoroughly dry before combine harvesting is attempted.

Generally, it is unwise to attempt to clean flaxseed thoroughly in threshing, as this may result in too much seed going over with the chaff and straw. This loss in many cases exceeds the cost of a separate recleaning job.

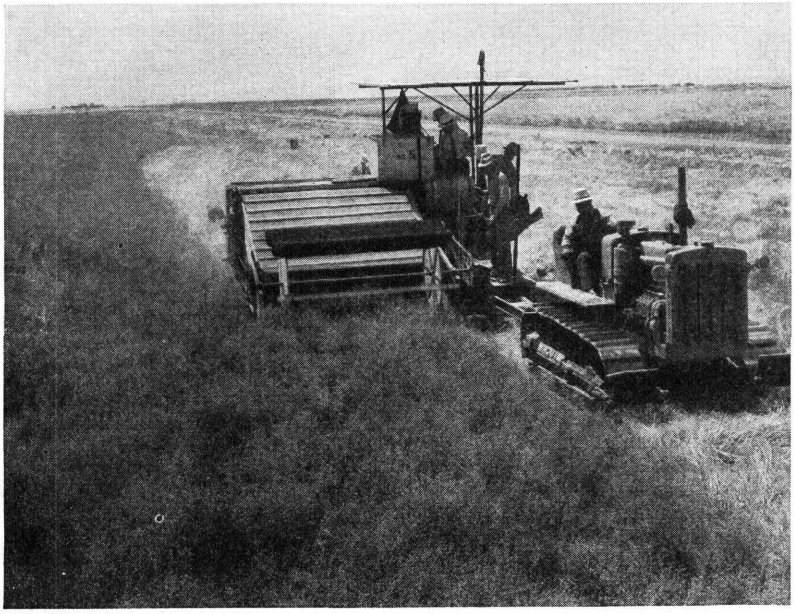


FIGURE 8.—The new Calflax combine is especially designed for harvesting flax in the dry climate of California. It is provided with parallel rollers 8 feet long, which crush the flax bolls without injury to the seed. The seed is cleaned with screens and fan and elevated to a recleaner on top of the machine, which completes the cleaning. The seed is bagged and dropped off through a chute at the right of the machine.

CLEANING FLAXSEED

Some linseed mills will accept flaxseed containing dockage up to 30 or 40 percent. However, it should be borne in mind that the grower must pay the extra cost of freight on the dockage and that he receives little or no return for it. Most flaxseed as it comes from the thresher contains 10 percent or more of dockage, which is made up of weed seeds, cracked flaxseed, grain, and chaff. These screenings have a considerable feed value, depending on the kinds of grain and weed seeds present.

By recleaning flaxseed before shipping it to market the flax grower saves the cost of shipping charges and has the screenings for feed. Screenings should be finely ground to prevent scattering weed seeds on the farm.

The ordinary fanning mill is a practical type of seed cleaner for farm use. In the type of mill shown in figure 9, two principles are operative in cleaning the seed: (1) Separation by screens or sieves and (2) separation by weight. As the seed falls through the top sieve, which has meshes 4 by 14 per inch, the larger weed seeds and grain are separated from the flaxseed. The second sieve, with round holes one-fourteenth of an inch in diameter, will separate the small weed seeds. Then, with the air blast properly regulated, the light, immature flaxseeds, light weed seeds, and trash will be blown out as the flax falls through the air blast to the receiving box below. Commercial grain cleaners, which move from farm to farm, may be more economical and efficient where a large quantity of seed is to

be cleaned. These commercial cleaners are used extensively in California.

Flaxseed intended for sowing should be thoroughly cleaned before being stored. Only dry, well-developed seed should be saved, and stored in a dry place. The use of only dry, plump, clean seed should aid in reducing the danger of spreading wilt and rust, the spores of which are carried on immature seeds, chaff, or broken stems. This is discussed further under Diseases.

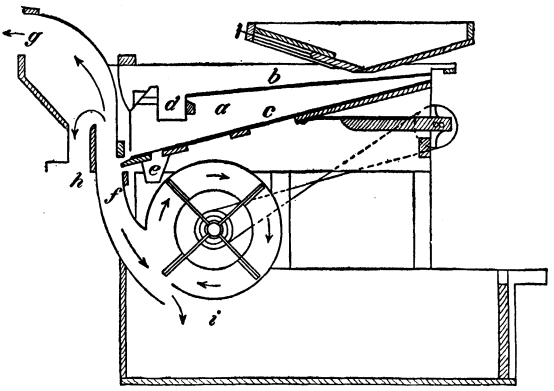


FIGURE 9.—A good type of grain-cleaning mill that will reclean flax for seed. *a*, Shoe, carrying upper (*b*) and lower (*c*) screens; the shoe is given an end shake by means of an eccentric bearing operated by the crankshaft. *d*, Spout which carries off coarse material separated by the upper sieve (*b*); an upper sieve with meshes 4 by 14 per inch will separate wheat from flax. *e*, Screening spout, which receives small weed seeds separated by the lower sieve. *f*, An air current driven up through the falling grain carries off chaff and dust through the hood (*g*); light seeds fall through the open space (*h*). *i*, Grain box, which receives the clean grain. Cone pulleys on the fan and drive shaft make it possible to drive the fan at any speed necessary to remove light seeds and trash.

DISEASES

The principal diseases of flax in the North Central States are wilt, rust, heat canker, pasmo, and certain seedling diseases. So far as the writers have observed none of these diseases has occurred in the Imperial and San Joaquin Valleys of California, although rust often occurs in the humid coastal section of Oregon.

WILT

Wilt is a fungus disease that may attack flax plants at all stages of growth, causing them to wilt and die. The fungus grows upon live flax plants but continues to live on dead organic matter in the soil. When once introduced it may remain in the soil for an indefinite period. Figure 10 shows the first appearance of wilt in a field frequently cropped to flax. In many cases such spots of wilt appear in the second or third crop. Authentic cases are known where a crop of flax was grown on new land without noticeable loss from wilt, but on the same land 5 years later the crop was entirely destroyed by wilt. The fungus apparently was introduced into the soil with seed for the first crop and increased during the 5-year period until it was widely distributed throughout the soil.

Wilt usually is introduced into a clean soil by sowing infected seed; therefore, the use of clean, wilt-free seed is of prime importance if new land is to be kept free from wilt. Seed treatment is of doubtful value in control of the disease. Although it is desirable to prevent the introduction of wilt on new land as long as possible, the most practicable method of control is to grow a wilt-resistant variety. Bison, a wilt-resistant variety, is grown extensively in the North Central States. A number of wilt-resistant strains of Indian and

Argentine flax are being grown at the California Agricultural Experiment Station. These will be ready for increase and distribution in case wilt ever becomes a menace to flax production in that State.

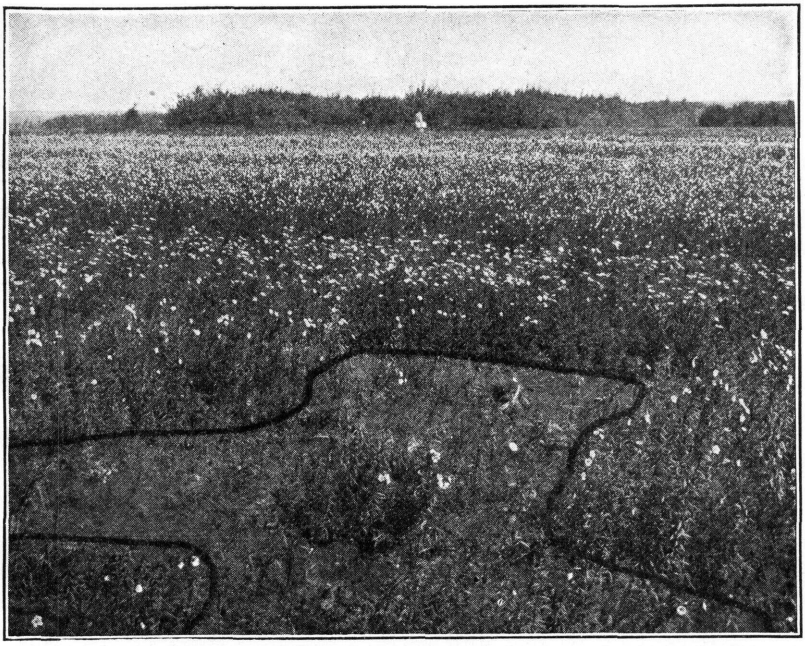


FIGURE 10.—A field in North Dakota frequently cropped to flax, showing the first appearance of flax wilt in spots. A wilt-resistant variety can be grown on such land without loss from wilt.

RUST

In wet climates or on low damp soils, rust may damage flax, especially if the crop is late in ripening. It is not likely to be of any importance in the dry summer climate of the interior valleys of the Pacific Coast States.

The disease appears as bright-orange pustules on the leaves and green stems. Later in the season the spots turn darker because of the appearance of the brownish spores that overwinter on the straw. As new infection comes from the old straw and stubble of the previous year, a rotation that avoids putting flax on the same land 2 years in succession will help to control this disease. A few varieties are immune from rust. These include a few strains of Argentine, Indian, Newland, Ottawa 770B, Bolley Golden, and a number of hybrid strains developed by breeding at Federal and State agricultural experiment stations. The most promising method of control is breeding resistant varieties.

HEAT CANKER

Heat canker is caused by high temperatures at the surface of the soil. It usually occurs in thin stands, when the plants are small, and when the soil has been compacted by rain. The young stems are girdled at the point where they are in contact with the hot surface

soil and the plants finally break off in the wind. Heat canker often does some damage to late-sown flax in the northern Great Plains, but it has not been observed in the Pacific Coast States. The best control measure for spring-sown flax appears to be early seeding at a rate sufficient to insure a good stand of plants. This enables the plants to shade the soil before hot weather occurs.

PASMO

Pasmo first appears as yellow-brown circular lesions on the seed leaves (cotyledons) and foliage of young flax plants. However, it is most readily recognized on the flax stems in the early ripening stage as irregular bands of brown mottling alternating with bands of green. It is not known how much damage pasmo causes. Fair yields of seed are obtained when the disease appears to be prevalent. It probably does more damage to fiber flax than to seed flax. Argentine varieties appear to be more susceptible than others. Pasmo is known to be carried on the seed; the introduction of infected seed into new territory should be avoided so far as possible.

SEEDLING BLIGHT, DAMPING-OFF, AND ANTHRACNOSE

Occasionally flax is injured by certain seedling diseases that cause damping-off of the young plants, or serious blighting of the crop after irrigation. Anthracnose (*Colletotrichum lini* Peth. and Laf.) is the cause of this injury in some cases in the North Central States. In other cases the organism that causes the disease has not been determined. Seed treatment with a dust fungicide has increased the stand and yield of flax in some seasons in experimental tests in Iowa, whereas in other seasons seed treatment has had little or no effect. Rotation of crops, the use of bright mature seed, and seed treatment appear to be the best methods of control.

INSECTS

In the flax area of the North Central States grasshoppers and field crickets occasionally do considerable damage. Grasshoppers damage standing flax chiefly by eating the small stems to which the bolls are attached, causing the bolls to drop. Crickets eat the seeds, both on standing flax and in the shock. Where these insects are abundant they may do serious damage.

In some parts of the San Joaquin and Sacramento Valleys of California the false chinch bug (*Nysius ericae minutus* Uhl.) did considerable damage to flax in 1936 where the crop was exposed in small fields. This insect breeds in the open grasslands of the valley and in some years infests cultivated crops such as flax. It is a sucking insect and feeds chiefly on the green bolls, causing the seeds to shrink and become light. No economical method of control has been found.

In the Willamette Valley of Oregon, the larva of *Cnephasia longana* Haw., known locally as strawberry worm, has done some damage to fiber flax. It feeds chiefly on the young growing tips of flax, thus checking its growth and causing it to branch, which is detrimental to the yield and quality of fiber. It probably would not be so damaging to seed flax.

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